NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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REPORT NUMBER 978

COLD WEATHER GOGGLES:

II. Performance Evaluation

by

S. M. Luria

Naval Medical Research and Development Command
Research Work Unit M0095-PN.001-1040

Released by:

W. C. Milroy, CAPT, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

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SUMMARY PAGE

Problem

To assess the effects of wearing different goggles designed to protect the eyes from the cold on the performance of tasks which are important to the Marines in the field.

Findings

Acuity, depth perception, color perception, vision through binoculars, and riflery were compared with the subjects wearing different goggles. Except for color perception through the saturated yellow goggles and riflery with the most distorted goggles, there were no significant changes in performance as a result of wearing the goggles.

Applications

The standards of quality control for optical distortions adhered to by the manufacturers of commercial goggles permit the satisfactory performance of a representative selection of tasks of importance to the Marines. It appears, therefore, that there would be no problem in producing goggles which have a selection of optimal characteristics for Marine applications in the cold.

ADMINISTRATIVE INFORMATION

This investigation was undertaken under Naval Medical Research and Development Command Work Unit M0095-PN.001-1040 - "Protective devices for the eye in cold weather." This report was submitted for review on 25 Feb 82 and approved for publication on 23 Mar 1982. It was designated as NavSubMedRschLab Report No. 978

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ABSTRACT

The performance of various tasks of importance to the Marines was compared when the subjects were wearing different goggles designed to protect the eyes from the cold. Color perception through yellow goggles and riflery through the most distorted goggles were degraded, but there were no significant impairments in acuity, depth perception, or vision through binoculars. The optical standards adhered to in the manufacture of commercial goggles appears to permit the satisfactory performance of practical tasks.

INTRODUCTION

Vision is often degraded in the winter if the eyes are not protected from the extremes of cold and radiant energy. In a previous report, we evaluated the optical characteristics of a selection of commercially available goggles designed for that purpose. The goggles were found to vary in their optical quality and other characteristics, and we suggested specifications for an optimal pair of goggles.[1]

Certain goggles were then selected for evaluation in tasks of practical importance to the Marines. The aim was to see if variations affected the performance of such tasks as contrast sensitivity, color and depth perception, acuity through binoculars, and riflery. It seemed possible that distortions in the critical viewing area would reduce acuity, that prism distortions might affect color perception, and that the mere wearing of goggles might interfere with the ability to look through field glasses or sight a rifle.

There is a general relationship between the type and magnitude of refractive error and visual acuity, but different investigators have proposed somewhat different figures. Sloan[2] estimates that each -.18 D of error leads to a reduction of one line in Snellen acuity. Thus, -.75 D of refractive error is associated with a Snellen acuity of about 20/40, and -1.00 D of error with an acuity of 20/60. Hirsch[3] suggests that -.50 D of error leads to an acuity of 20/25, and -1.00 produces an acuity of 20/65. Other investigators suggest slightly different relationships, but they are roughly comparable. However, none of the goggles previously tested[1] had more than -.20 D of spherical refractive power. On the other hand, five of the 13 goggles tested had rather severe optical distortions according to current military specifications.

Prismatic deviations can degrade stereoscopic depth perception, but large amounts are generally required. Carter[4] has reported that 2 prism diopters are necessary to produce spatial distortion. This is much greater than the magnitudes of prismatic deviation found in the goggles, which did not exceed 0.6 diopters.

There was little doubt that the colored filters found in some of the goggles would interfere with color perception. Farnsworth[5] tested the effects of eight sunglasses on performance on the Farnsworth-Munsell 100-Hue Test. Their colors were neutral, yellow, rose, and three shades of green. Farnsworth found that the neutral and green filters produced a "barely detectable decrement" in color perception. One of his "neutral" filters was a polaroid filter which while appearing neutral actually transmitted two bands of wavelengths, one peaking at 510 nm and another which rose sharply beyond 600 nm. This filter resulted in some increase in the errors on the blue-green and red panels of the test, although the error score was still within the normal range. Only the rose and yellow filters caused an appreciable increase in errors. The mean score with the former was comparable to scores for tritanomalous observers and that for the yellow was as deficient as those made by dichromats.

Finally, even if the goggle filters did not introduce some optical distortion, it was quite conceivable that the goggle-frames themselves might interfere with the ability to use field glasses or to sight rifles, since the wearer might not be able to position his eyes where he wishes.

For each task, those goggles which were deemed most likely to degrade performance were included in the selection. Table I lists the goggles used in the tests and gives the ratings of viewing distortion and the horizontal deviations measured in the previous evaluation.[1] The goggles are coded according to their color and degree of viewing distortion, with 1 being the least distortion and 9 the most. Thus, Y-6 refers to a yellow goggle with a magnitude of viewing distortion which was rated to be 6.

CONTRAST SENSITIVITY

Method

Vertical square-wave gratings were generated on a Hewlett-Packard cathode ray tube (CRT) with a P31 phosphor. At the viewing distance of 150 cm, the screen subtended $10^{\circ} \times 7.6^{\circ}$ visual angle. Six spatial frequencies were chosen to sample the contrast sensitivity function. The mean luminance was about 2 cd/m^2 and the surround was illuminated to about .1 cd/m^2. Thresholds were measured with the ascending method of limits. With the subject wearing a given pair of goggles, a spatial frequency was selected and presented below threshold. Its contrast was increased in preselected steps until the subject could report its size. A new frequency was selected and the process repeated. This continued until each of the six frequencies had been presented three times. Then a new pair of goggles was put on and the procedure repeated.

Four goggles which showed a high degree of viewing distortion[1] were selected for testing. Of these, two had neutral filters (NM-8, NP-9)--the latter being polarized--one was yellow (Y-6), and the fourth had a rose filter (R-8). In addition, thresholds were measured with no goggle.

The subjects viewed the CRT through an aperture positioned immediately in front of the eyes. The aperture held neutral density filters which equated the goggles for photopic luminance taking into account the spectral distribution of the goggles and the CRT phosphor. The neutral density filters were also tested for the same optical distortions as were the goggles and showed no measurable distortions.

Three subjects were tested. All were color normal, and none wore a spectacle correction.

Results

The mean thresholds at each spatial frequency are shown for each pair of goggles in Fig. 1. None of the goggles reliably interfered with contrast sensitivity. The thresholds obtained when the subjects were wearing no goggles typically appear in the midst of the thresholds for the goggles. An analysis of variance showed no significant differences between the goggles at any spatial frequency.

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Enclosure (1)

Because of difficulties in obtaining sufficient contrast at 15 cpd, the viewing distance was increased to 230 cm to permit the use of larger gratings, and the thresholds for 10 and 15 cpd were repeated. Moreover, in an effort to increase the difficulty and sensitivity of the task, another repetition was made with the targets exposed for only .5 second. Thresholds were taken with the subjects wearing no goggles and the NP-9 goggles, which showed the most distortion. The thresholds for the continuous target presentation are included in Fig. 1. All the additional thresholds are given in Table II. It is clear that there are no threshold differences between viewing with no goggles and viewing with the distorting goggles.

The dotted line in Fig. 1 reproduces the contrast sensitivity function obtained with the same apparatus under similar conditions in a previous study[6] in which the subjects did not view the CRT through ND filters. In order to equate the luminosity of the display as seen when wearing no goggles with that seen through the most dense goggles, a .7 ND filter was required. The sensitivity function in the present study, as can be seen in Fig. 1, is about .7 log unit above the function obtained in the previous study. In other respects, they are similar.

STEREOSCOPIC DEPTH PERCEPTION

Method

Stereoacuity was measured with a three-rod Howard-Dolman apparatus. The two outer rods were fixed in position at a distance of 6 m from the subject's eyes; the middle rod was movable. The black rods subtended $.06^{\circ}$ visual angle and were separated by $.72^{\circ}$. They were visible through a $1.3^{\circ} \times 3.5^{\circ}$ window in the dark gray faceplate and were seen against a white background illuminated to 70 cd/m^2.

The subjects viewed the apparatus through an aperture set immediately in front of the eyes. The aperture held neutral density filters which equated the various goggles and the no-goggle condition for photopic luminance.

Four goggles which exhibited severe viewing distortion and a range of prismatic deviations[1] were chosen for testing. They and the no-goggle condition were tested in a different random order for each subject.

Thresholds were measured with the method of constant stimuli. The movable rod was set at various position, the window of the apparatus opened, and the subject judged whether the rod was closer or farther than the fixed rods. A frequency of seeing curve was drawn on cumulative probability paper and the thresholds taken as the 50% point.

Three subjects participated. Two had good stereoacuity, and one had relatively poor stereoacuity.

Results

Table III gives the location errors and the variability of the points of subjective equality for each subject with the different goggles as well as with no-goggles. There is no indication that the goggles degraded stereoacuity. The mean localization error is greater for the Y-6 goggles only because of the great error by subject B whose stereoacuity is poor and unreliable. It appears to be purely chance that his localization error was so great for that particular goggle. For the variability, a more common indicator of stereoacuity, it is quite clear that the goggles did not degrade performance. Neither the mean errors nor the variabilities were significantly different for the various goggles according to the Friedman analysis of variance by ranks.

COLOR PERCEPTION

Method

Color perception was tested with the Farnsworth-Munsell 100-Hue Test, administered out-of-doors. Five goggles were selected to sample the range of colors in which the goggle filters are available, neutral, neutral with a distinct yellow tinge, greenish-yellow, saturated yellow, and rose. The goggles were not equated for differences in transmittance (which varied from .21 for the NM-8 to .80 for the Y-6), since the goal was to see if these goggles would degrade color perception as they would normally be used.

Three subjects were tested, two of whom had taken the F-M 100-Hue Test many times.

Results

Table IV gives the error scores for the subjects with each goggle. The error scores are very low for all the goggles except the yellow; the mean score with the yellow goggles excluded is 11, which would place the observers in the top 4% of color normals.[7] The mean error score for the yellow goggles is in the bottom 3.5% of color normals.[7] This is a significant degradation ($p < .02$) according to the Friedman analysis of variance by ranks.

Table V gives the mean time taken to complete the test with each goggle. Although the yellow goggles, as expected, produced the longest times to complete the test, the differences were not significant according the Friedman test.

ACUITY THROUGH BINOCULARS

Method

Acuity was measured using a series of high contrast black-and-white grid targets, positioned 3700 feet from the subjects, according to a U. S. Geodetic Survey map. Thresholds were measured using the method of constant stimuli. The subjects reported whether the gratings were vertical or horizontal. Solid gray targets, matched in mean luminance to the gratings, were inserted to check that the subjects were not guessing. The targets were 15 inches square and, seen through the 7-power binoculars, subtended 8 minutes visual angle. Observations were made for short periods at the same time each day, so that the position of the sun on the targets was constant. The binoculars were held by the subjects; there was no tripod or mount.

Two goggles were chosen for testing, one which had the maximum viewing distortion (NP-9) and one which had very low distortion (GY-1). In addition, thresholds were measured with the subjects wearing no goggles. The three conditions were counterbalanced among six subjects.

Five staff members of the laboratory and one corpsman from the Base Hospital volunteered to observe. None wore spectacle corrections. Only two were experienced in psychophysical experiments.

Results

The mean width of the stripes at threshold for the six subjects is given for each of the three conditions in Table VI. Although the threshold through the goggle with the large viewing distortion was the poorest, the differences between the thresholds were not significant, according to an analysis of variance.

Table VI also gives the mean standard deviations of the thresholds of the six subjects for each condition. That is, when measured with the method of constant stimuli, the standard deviation of each subject's thresholds may easily be calculated. These six standard deviations were averaged for each of the three conditions and indicate the precision with which the targets could be resolved under each condition.

The mean standard deviation is highest for the distorting NP-9 goggle, although an analysis of variance again indicated no significant differences between the three conditions.

RIFLERY

Method

This study was carried out on a military rifle range immediately after the "shooting-for-record" which is required periodically for every Marine. Each subject thus had a "practice" period immediately before the experiment. Sixteen men from the Naval Submarine Base Marine Barracks volunteered to participate. None wore spectacles. The shooting was conducted using the procedures under which they are normally tested. After donning their goggles they were allowed one minute in which to fall to the prone position, insert the clip, and fire 10 shots at targets 300 yards away. The riflemen were assigned to their positions at random, and their score sheets were turned in to the experimenter immediately at the end of the shooting. The men did not learn their scores until the experiment was completed. At that time, they were allowed to see their scores, and comments about the goggles were solicited.

Two goggles, one with very low optical distortion (GY-1) and one with the most optical distortion (NP-9) were chosen for testing. In addition, a pair of goggle frames without a filter was also tested to assess the effects of the frame alone. The fourth condition was no goggles at all. These four conditions were counterbalanced among the 16 subjects.

Results

The subjects were picked from the volunteers by their commanding officer. It appears that he began by choosing the men whom he knew to be the best shots in the group. Of the first 8 men selected, 7 were near perfect shots. Of the second group of 8 men selected, only 2 were superior shots. There were, thus, a group of superior riflemen and a group of average riflemen. This dichotomy is of interest since it is possible that the goggles might affect average riflemen differently than superior ones.

Table VII gives the mean scores (as scored by the Marines) for each goggle for the total group and for the superior and average riflemen separately. A perfect score for the 10 shots would have been 50. There were no significant differences between the mean scores for the total group; neither the filters nor the empty frame significantly degraded their shooting, despite the fact that many men reported that the NP-9 goggle noticeably distorted their vision: they complained that they had been unable to achieve a clear image of both the sights and the target while wearing these goggles, whereas the GY-1 goggles were judged superior in this respect. Several men also felt that the "empty" frames also imposed a handicap, but this was not reflected in the mean scores either.

A different picture emerges when the superior riflemen were analyzed separately. The mean score for the distorting NP-9 goggle was now noticeable worse, and the differences between the conditions were significant ($p < .05$) according to a Friedman analysis of variance by ranks. This occurred because the no-goggle score was significantly better than the goggle scores. There were no significant differences between the three goggle conditions, according to the Friedman test. There were, also, no significant differences between the conditions for the average riflemen.

DISCUSSION

Color perception through the saturated yellow goggles and rifle accuracy by the superior group of riflemen were the only tasks significantly affected by any of the goggles. However, the mean error score for the three subjects on the color perception test remained within normal limits, and the degradation of shooting accuracy, while statistically significant, was not very great. Contrast sensitivity, stereoscopic depth perception, and the ability to see through binoculars were not significantly affected. It appears, then, that the level of optical quality which can readily be achieved commercially will adequately maintain the performance of the Marines.

The failure of the goggles with the greatest amount of viewing distortion to significantly reduce either contrast sensitivity or acuity through field glasses is, however, surprising. The standards by which they were evaluated were formulated for testing aircrew visors and are, therefore, stringent. Nevertheless, it was not expected that no degradation of acuity would be revealed.

Typically, the usual reaction to such a finding is to assume that the test is not sensitive enough. There can be few such doubts, however, about the contrast sensitivity function. What seems more likely is that the standards by which the aircrew visors are evaluated have been set very conservatively in order to err on the side of safety. For these tests, a degree of distortion which is easily measurable apparently produces no significant effects on performance.

In addition to degrading riflery, however, there is some suggestion in the results that the most distorting goggles were on the verge of degrading acuity through the binoculars. This suggests that some additional distortion might well result in a significant degradation of performance here. It would be of interest to investigate this possibility, since such a finding would permit the specification of the degree of optical distortion which must not be exceeded for such a task.

Color perception was degraded by the saturated yellow filters, as previously found by Farnsworth.[5] Those colors perpendicular to the yellow-purple axis on the color diagram were especially affected. Somewhat surprisingly, the "rose" goggles in this study did not interfere with this task, although the "rose-smoke" goggles tested by Farnsworth did degrade color perception. There appear to be several reasons for this difference. First, the spectral transmittances of the two goggles are dissimilar. The present goggles transmit rather equal amounts of light from 400 to 600 nm and are given their reddish color by increasingly higher transmittances above 600 nm.[1] Farnsworth's goggles, on the other hand, had a peak transmittance at about 610 nm with decreasing transmittance on either side. From 400 to 500 nm, the transmittance was about 5%, whereas the present goggles transmit about 45% from 400 to 500 nm. There is, therefore, a more balanced transmittance with the present goggles, and one would expect better color perception with them.

Second, the testing in this study was carried out in sunlight, under much higher luminance levels than is usually the case. There is some evidence that color discrimination improves with increased luminance.[8] This may also have produced better performance with the yellow goggles than Farnsworth obtained.

Third, the three observers in the present study all exhibited superior color vision, in part because two of them had had extensive experience with the test.[9,10] Farnsworth tested 20 subjects; there is no mention of their having experience with the test, and the larger group increases the probability of the results being more average.

Finally, it may be noted that Harris and Cabrera[10] found no effects on the 100-Hue Test of a wide variety of tinted contact lenses, all of which, of course, had high transmittances and no sharp spectral cut-offs.

The reduction in color perception may be a problem in certain cases. There will be occasions when color-coded maps must be read or various colored signals perceived. At such times the goggles would have to be removed, at least for a short period of time. On the other hand, there appear to be advantages to having yellow filters in such goggles,[11,12] and it is doubtful if acute color perception is required for most tasks carried out by Marines in the field. Even severely color defective men are excluded only from certain specialties in the Marine Corps.

It is possible that this problem can be resolved, however. It may be that a less saturated yellow filter--that is, a filter without such a sharp cut-off at 500 nm--will improve color perception while at the same time maintaining the advantages for such visual processes as depth perception.

One measure which was considered in the previous evaluation, but not in the present one, is crticial. It is resistance to fogging. There is no question that if the goggles are fogged, every one of the tasks tested in this study would suffer. These results, therefore, indicate only that the optical distortions produced by the filters do not degrade performance; they do not lead to the more general conclusion that goggles will not degrade performance. A persistent problem with most goggles is that they do fog under certain conditions. Unless that can be eliminated, any goggles will be used only intermittently.

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Table I. Sum of horizontal deviations (Diopters) and ratings of viewing distortions

Goggles	Horizontal Deviations	Viewing Distortions*
Yellow (Y-6)	.00	6
Yellow-Neutral (YN-4)	.19	4
Green-Yellow (GY-1)	.14	1
Rose (R-8)	.46	8
Neutral-Polaroid (NP-9)	.52	9
Neutral-Military (NM-8)	.12	8

* According to current military specifications, a viewing distortion rating of 6 or higher is unacceptable.

Table II. Mean contrast sensitivity for constant target duration and 0.5 second duration at a viewing distance of 230 cm with no goggles and with the distorting NP-9 goggles

Condition	Constant target duration		0.5 second duration	
	10 Hz	15 Hz	10 Hz	15 Hz
No goggles	.059 ±.004	.180 ±.010	.053 ±.013	.190 ±.024
Distorting goggles (NP-9)	.053 ±.006	.185 ±.032	.058 ±.017	.170 ±.060

Table III. Stereoacuity of individual subjects with various goggles

Observer	Localization Error (sec arc)				
	No goggle	Distorting Goggles			
		Y-6	NM-8	R-8	NP-9
T	5.55	3.05	4.16	7.12	5.09
S	5.74	3.24	3.24	4.44	3.70
B	5.55	25.90	3.70	3.70	9.25
Mean	5.61	10.73	3.70	5.09	6.01
	Variability (sec arc)				
T	4.16	1.94	2.13	2.96	2.31
S	2.59	2.31	5.52	5.18	3.42
B	39.78	35.15	17.58	13.88	20.35
Mean	15.51	13.14	8.42	7.34	8.70

Table IV. Error scores on the F-M 100-Hue Test through various goggles

Subjects	Goggles				
	GY-1	R-8	NM-8	YN-4	Y-6
CS	4	4	8	4	48
SK	32	8	12	16	72
SL	12	28	8	0	112
Mean	16	13.3	9.3	6.7	77.3

Table V. Mean times to complete the Farnsworth-Munsell 100-Hue Test while wearing various goggles

Goggles	Time (min)
GY-1	9.00 ±3.76
R-8	8.98 ±3.69
NM-8	9.93 ±4.11
YN-4	9.28 ±2.89
Y-6	10.62 ±1.93

Table VI. Mean stripe width of the target at threshold and mean standard deviation of the threshold target width through the different goggles

Goggles	Mean stripe width (inches)	Mean standard deviation
None	1.27	.20
NP-9	1.38	.22
GY-1	1.24	.14

Table VII. Mean rifle scores

Group	No goggle	Empty frame	NP-9	GY-1
Total (N=16)	40.5 ±10.6	40.2 ±12.2	40.4 ±9.5	39.5 ±12.9
Superior (N=9)	47.7 ±1.9	47.4 ±1.5	46.4 ±1.9	47.0 ±2.0
Average (N=7)	31.3 ±9.9	30.9 ±13.7	32.6 ±9.6	29.9 ±14.8

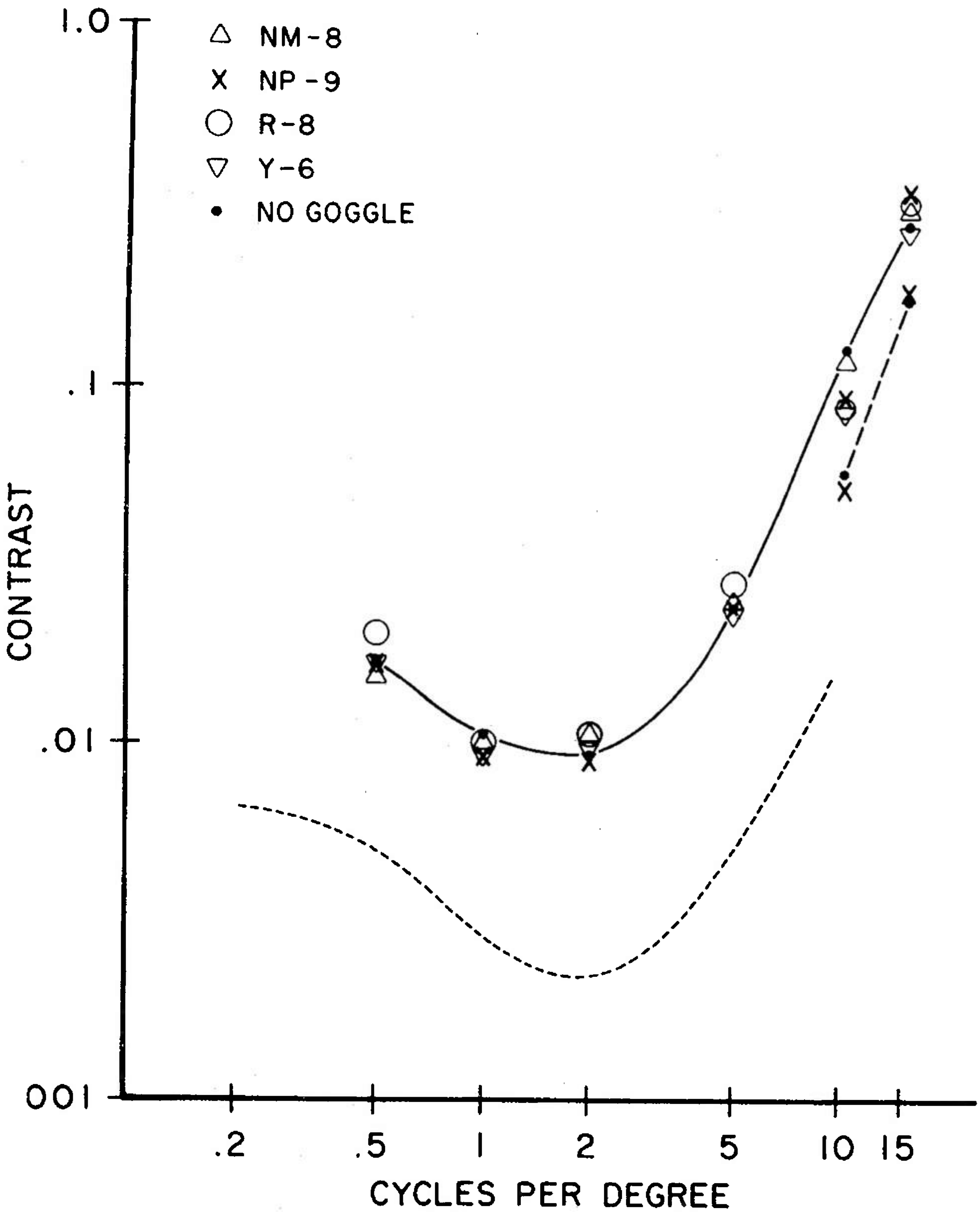

Fig. 1. Mean contrast sensitivity of three subjects for vertical square waves viewed through various goggles equated for photopic luminance. The solid line shows the mean sensitivity when wearing no goggles but with target luminance equated to that seen through the goggles. The dashed line gives the mean thresholds with no goggles and with the NP-9 goggles remeasured at a longer viewing distance to permit the use of larger gratings. The dotted line shows the mean sensitivity of four subjects in a previous study when the targets were at a luminance of .7 log unit higher.

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The performance of various tasks of importance to the Marines was compared when the subjects were wearing different goggles designed to protect the eyes from the cold. Color perception through yellow goggles and riflery through the most distorted goggles were degraded, but there were no significant impairments in acuity, depth perception, or vision through binoculars. The optical standards adhered to in the manufacture of commercial goggles appears to permit the satisfactory performance of practical tasks.

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